AD-764 149

CORROSION OF NICKEL PLATED STEEL AT TROPICAL ENVIRONMENTS

Fred Pearlstein, et al

Frankford Arsenal
Philadelphia, Pennsylvania

1971

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

AD 764149

AD

REPORT A71-16

CORROSION OF NICKEL PLATED STEEL AT TROPICAL ENVIRONMENTS

by

FRED PEARLSTEIN
and
LEONARD TEITELL

November 1971

AMCMS Code: 502E.11.294
DA Project: 1T062105A328

This document has been approved for public release and sale; its distribution is unlimited.

DEPARTMENT OF THE ARMY
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

8

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) FRANKFORD ARSENAL Philadelphia, PA 19137	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

CORROSION OF NICKEL PLATED STEEL AT TROPICAL ENVIRONMENTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Research Article

5. AUTHOR(S) (First name, middle initial, last name)

Fred Pearlstein

Leonard Teitell

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1971	7	2

8a. CONTRACT OR GRANT NO. AMCMS Code 502E.11.294	9a. ORIGINATOR'S REPORT NUMBER(S) A71-16
b. PROJECT NO. DA Project 1T062105A328	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	AMMRC

13. ABSTRACT

Double-layer nickel deposits were compared with single-layer deposits (with chromium flash topcoats) for corrosion protection provided to steel exposed at several tropical environments. The double-layer nickel plated steel was considerably more corrosion resistant than single-layer nickel at tropical marine and open field exposures. There was no apparent benefit to the double layer at rain forest exposure, however.

40μm (1.6 mil) total thickness of double-layer nickel was virtually completely protective to steel at the open field and rain forest sites over 35 months' exposure whereas 20μm thickness was not. At the coastal marine site, the 40μm double-layer coated specimens had only slight basis metal attack after 35 months' exposure.

Elimination of the chromium flash topcoat on 40 μm nickel deposits in some instances, appeared to improve resistance to basis metal attack but greatly reduced the surface tarnish resistance.

A semi-bright nickel electrodeposit with an electroless nickel topcoat was superior in corrosion protection to the conventional double-layer nickel electrodeposits of the same total thickness. However, the electroless nickel deposits tarnished badly at the tropical exposures.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Corrosion of Plated Steel						
Tropical Exposure						
Canal Zone Sites						
Nickel Plated Steel						
Double-layer Nickel Deposits						
Chromium Deposits						
Electroless Nickel Deposits						
Semi-bright Nickel Deposits						
Bright Nickel Deposits						

ABSTRACT

Double-layer nickel deposits were compared with single-layer deposits (with chromium flash topcoats) for corrosion protection provided to steel exposed at several tropical environments. The double-layer nickel plated steel was considerably more corrosion resistant than single-layer nickel at tropical marine and open field exposures. There was no apparent benefit to the double layer at rain forest exposure, however.

A 40 µm (1.6 mil) total thickness of double-layer nickel was virtually completely protective to steel at the open field and rain forest sites over 35 months' exposure, whereas 20 µm thickness was not. At the coastal marine site, the 40 µm double-layer coated specimens had only slight basis metal attack after 35 months' exposure.

Elimination of the chromium flash topcoat on 40 µm nickel deposits in some instances appeared to improve resistance to basis metal attack but greatly reduced the surface tarnish resistance.

A semi-bright nickel electrodeposit with an electroless nickel topcoat was superior in corrosion protection to the conventional double-layer nickel electrodeposits of the same total thickness. However, the electroless nickel deposits tarnished badly at the tropical exposures.

Corrosion of Nickel Plated Steel at Tropical Environments

F. PEARLSTEIN and L. TEITELL, *Frankford Arsenal, Philadelphia, Pa.*

ARMY equipment is required to function effectively in a wide variety of environments; therefore, it is necessary to provide adequate protection against corrosion of the various components. Protection of steel components in tropical environments has been particularly important in view of military activities in tropic and semi-tropic regions. This study evaluated the effectiveness of single and double-layer nickel[1,2] deposits for providing corrosion protection to steel exposed to tropical environments.

Procedure

AISI 1010 steel panels were plated with several thicknesses of levelling, semibright, sulfur free nickel and the same total thickness of double-layer nickel. The bright nickel deposit thickness consisted of approximately 25% of the total. A conventional 100:1 ratio chromic acid-sulfate solution was used to apply .5 μm (0.02 mil) thickness of chromium topcoat upon the nickel. One group of specimens with 15 μm (0.6 mil) semibright nickel was coated further with 5 μm (0.2 mil) electroless nickel(1) deposit.

Several exposure sites in the Fort Sherman area of the Panama Canal Zone were selected for conducting the corrosion tests. One site was on a breakwater extending into the Caribbean where considerable sea spray was produced from waves breaking on the rocks. An open field site was available approximately 600 meters from the sea at the nearest point and 1250 meters away in the direction of prevailing winds. The third exposure site was located under the canopy in the tropical rain forest of Fort Sherman.

Results and Discussion

Results of exposure tests (Tables 1a and 1b) indicated that double-layer nickel deposits are superior to single layer nickel (all with chromium topcoat) for protection of steel exposed at the tropical marine site. However, 40 μm (1.6 mils) total thickness is necessary to provide effective protection for as little as nine months' exposure; 20 μm deposits are not adequate. After 35 months' marine exposure, only the 40 μm double-layer deposits were protective against severe basis metal attack. These panels (Figure 1) had a number of small areas (1 to 2 mm diameter) of very light rust but little attack of the basis metal was evident. Similar results were obtained with the 40 μm double-layer nickel deposits without chromium topcoat except that there was even less evidence of basis metal attack.

Double-layer nickel deposits were clearly superior (Figure 2) to single layer nickel in providing corrosion protection to steel exposed at the open field site. However, double-layer deposits of 20 μm (0.8 mil) thickness or less were not completely protective after 35 months. The 40 μm double-layer was protective and of generally excellent appearance, though a number of shallow pits were visible which apparently extended only to the semibright nickel

TABLE 1a — Corrosion of Plated Steel at Three Tropical Exposure Sites

No.	Coating Thickness, μm (mil) Semibright Ni	Bright Ni	Cr	Electroless Ni
A	10 (0.4)	—	0.5 (0.02)	—
B	20 (0.8)	—	0.5 (0.02)	—
C	40 (1.6)	—	0.5 (0.02)	—
D	40 (1.6)	—	—	—
E	7.5 (0.3)	2.5 (0.1)	0.5 (0.02)	—
F	15 (0.6)	5.0 (0.2)	0.5 (0.02)	—
G	30 (1.2)	10 (0.4)	0.5 (0.02)	—
H	30 (1.2)	10 (0.4)	—	—
I	15 (0.6)	—	—	5.0 (0.2)

(1) Composition: 35 g/l nickel sulfate · $6H_2O$; 4 g/l sodium citrate · $2H_2O$; 3.5 g/l sodium acetate; 15 g/l sodium hypophosphite · H_2O; and 0.002 g/l mercaptobenzothiazole (added from solution 10 g/l MBT in 0.2N NaOH). Temperature, 90 C (194 F). Initial pH, 5.0.

Reprinted from MATERIALS PROTECTION AND PERFORMANCE, Vol. 10, No. 11, pp. 30-32 (1971) November

TABLE 1b – Basis Metal Corrosion Ratings[1] (Average of Four Replicates)

No.	Marine (months)						Open Field (months)						Rain Forest (months)					
	4	9	15	21	29	35	4	9	15	21	29	35	4	9	15	21	29	35
A	1.3	0	0	0	0	0	1.4	1	0	0	0	0	5	5	3.9	3.9	2.8	2
B	1.8	1.3	0.3	0.1	0	0	4.8	2.3	1	1	0	0	5	5	4.4	4.3	4	3.5
C	2.3	1.8	1.0	0.6	0.4	0	5	4.3	1.9	1.1	0	0.5	5	5	4.4	4.4	4.4	5
D	3	1.9	1.5	1.0	0.3	0	3.3	3.0	2.9	2.6	1.5	1.5	5	5	3.4	4.3	4.0	4.3
E	2.5	1.5	1.3	1.0	0.3	0	4.8	3.5	2	1.5	0.6	0.5	5	5	3.8	3.4	2.1	2
F	3.8	2.9	1.6	1.6	1.1	1.8	4.5	4.6	3.5	2.9	2.6	2.3	5	5	4.5	4.5	4.3	2.8
G	5	4.8	3	2.9	2.9	3	5	5	4	3.8	3.4	4.5	5	5	4.6	4.0	4.0	5
H	5	5	4.8	3.9	3.8	4	5	5	5	5	5	5	5	4.4	4.1	4.1	4.0	4.8
I	4.5	4.5	4.5	4.5	3.1	4.5	5	5	4.8	4.8	4.8	5	5	5	4.5	4.5	4.5	5

[1] Rating	Degree of Corrosion	Estimated Area Affected (%)
5 =	None	0
4 =	Traces	<0.2
3 =	Slight	0.2 to 1
2 =	Moderate	1 to 5
1 =	Considerable	5 to 25
0 =	Very extensive	25 to 100

layer; virtually no signs of basis metal attack were observed. Omitting the chromium topcoat resulted in even more complete protection of the basis metal, but the surface was quite dull in appearance with extensive fine pitting present.

The rain forest was the least corrosive of the tropical environments to the nickel plated steel panels. However, even here, 20 μm (0.8 mil) nickel deposits were not completely protective over the 35-month exposure period, but 40 μm deposits were. There was no evidence of superiority of the double-layer over single layer nickel; in fact, slight inferiority was indicated. Omitting the chromium topcoat from the 40 μm deposits had little effect on basis metal protection, but the surface appearance was detrimentally affected by a tarnish film and fine surface pitting.

Considerably more protection was furnished to the steel basis metal by the 20 μm (0.8 mil) double-layer deposit, consisting of 15 μm of semibright nickel beneath 5 μm of electroless nickel, compared to any of the other 20 μm thick deposits. The 20 μm double-layer deposit, with the electroless nickel layer, gave approximately the same protection to the basis metal as the conventional double-layer deposits with twice the thickness, i.e., 40 μm. However, at all the test sites, the electroless top layer was tarnished badly and at the rain forest site was discolored with black blotches. Further studies are presently being conducted on double-layer coatings comprised of one or more electroless plated layers.

In a few instances, the ratings for basis metal corrosion were higher at the termination of this test (after 35 months'

Total Nickel 10 μm (0.4 mil) | Total Nickel 20 μm (0.8 mil) | Total Nickel 40 μm (1.6 mil)

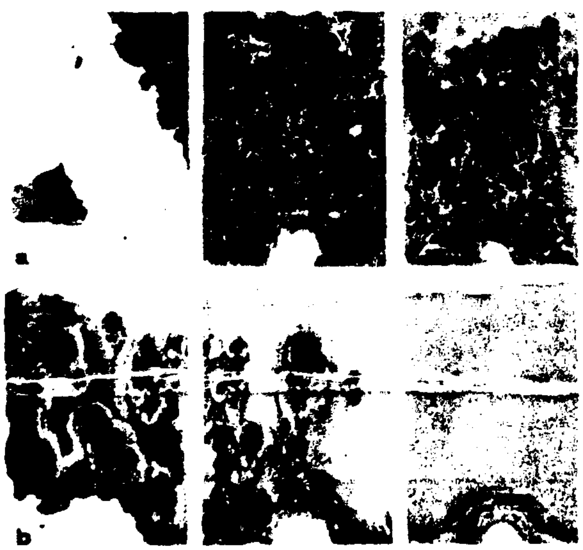

Figure 1 – Nickel plated steel panels (0.5 μm chromium topcoat) after 35 months' exposure to tropical marine environment. A—Single-layer nickel. B—Double-layer nickel.

3

Total Nickel 10 μm (0.4 mil) | Total Nickel 20 μm (0.8 mil) | Total Nickel 40 μm (1.6 mil)

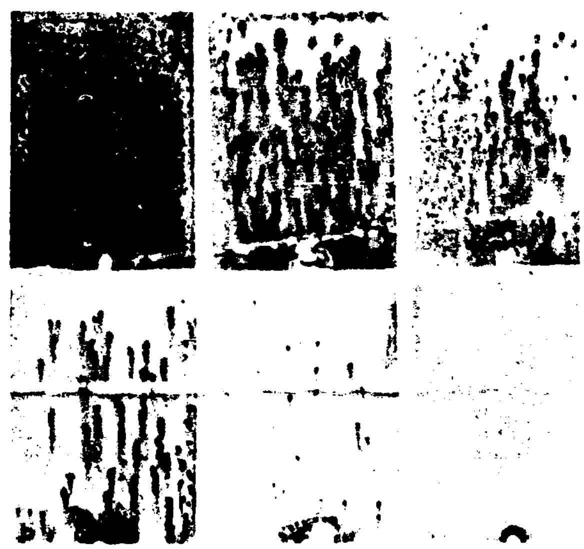

Figure 2 – Nickel plated steel panels (0.5 μm chromium topcoat) after 35 months' exposure to tropical open field environment. A–Single-layer nickel. B–Double-layer nickel.

exposure) than at earlier periods. The panels were cleaned only at the termination of the test, so adherent debris or microbial growths present on the panels at the time of the interim field inspections may have prevented the differentiation of basis metal corrosion from corrosion of only the protective metal coating.

Conclusions

Double-layer nickel deposits were considerably more protective to steel than single layer deposits at the tropical marine and open field sites but provided no advantage at the rain forest environment.

Conventional double-layer nickel deposits of 40 μm (1.6 mil) thickness were virtually completely protective to steel after 35 months' exposure at tropical open field or rain forest sites, while the 20 μm deposits were not. There was only slight basis metal corrosion of 40 μm double-layer nickel coated steel after this period of exposure to tropical marine environment.

The surface appearance was quite detrimentally affected by omission of the chromium topcoat, but in some instances, the basis metal protection was somewhat improved.

A semibright nickel deposit of 15 μm (0.6 mil) plus an electroless nickel topcoat of 5 μm (0.2 mil) thickness was considerably more protective than the conventional double-layer deposits of the same total thickness. However, the electroless nickel surface was badly darkened by environmental exposure, particularly at the rain forest site.

Acknowledgment

The authors wish to thank Mr. W. J. Pierce, Harshaw Chemical Co., Cleveland, Ohio, for his assistance in this program. The authors wish also to express appreciation to the staff of the U. S. Army Tropic Test Center Corozal, Canal Zone for their cooperation and assistance in exposing the specimens to the tropical environments.

References

1. M. M. Beckwith. *Plating*, [illegible] 402 (1960).
2. A. H. DuRose. *Tech. Proc. Am. Electroplaters' Soc.*, 50, 83 (1960).

FRED PEARLSTEIN, research chemist at the Frankford Arsenal, Philadelphia, Pa., is responsible for the research and development of inorganic corrosion protective coatings. He graduated from the Drexel University with a BS in chemical engineering. He is a member of the Electrochemical Society, the AES, and the NACE.

LEONARD TEITELL, research advisor at the Frankford Arsenal chemistry research laboratory, is in charge of research and development concerned with the effects of tropical environment on materials. He has a BSc from the Philadelphia College of Pharmacy and Science and an MA and a PhD from Temple University. He is a member of the ACS and the Society for Industrial Microbiology.